Speed of CMEs and the Magnetic Non-potentiality of their Source Active Regions

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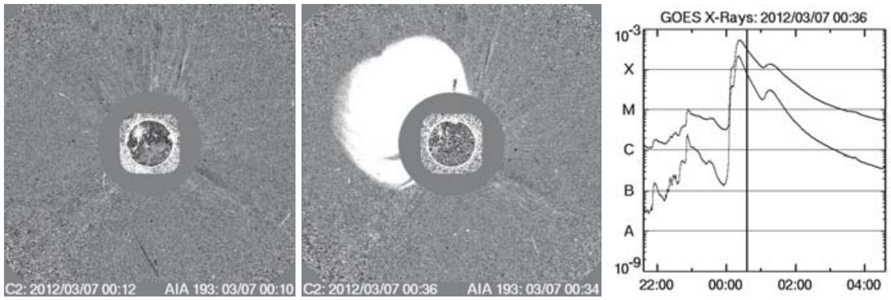
Abstract

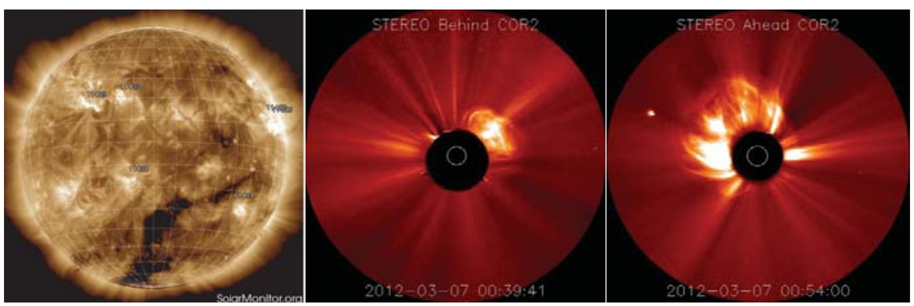
Most fast coronal mass ejections (CMEs) originate from solar active regions (ARs). Non-potentiality of ARs plausibly determines the speed of CMEs in the outer corona. Several other unexplored parameters might be important as well. To find out the relation between the initial speed of CMEs and the non-potentiality of source ARs, we identified over a hundred of CMEs with source ARs via their co-produced flares. The speed of the CMEs are collected from the SOHO LASCO CME catalog. We have used vector magnetograms obtained with HMI/SDO, to evaluate various magnetic non-potentiality parameters, e.g. magnetic free-energy proxies, twist, shear angle, signed shear angle, net current etc. We have also included several other parameters e.g. total unsigned flux, magnetic area of ARs, area of sunspots, to investigate their correlation, if any, with the initial speeds of CMEs. Our preliminary results show that the ARs with larger non-potentiality and area produce faster CMEs but they can also produce slow ones. The ARs with lesser non-potentiality and area generally produce only slower CMEs.

CME & Active Region Selection Criterion

An Example: An X-class flare occurred in the upper-left at 00:02:00 UT; 22 minutes later a CME appeared. The largest AR in that area is 11429, which produced flare/CME eruption.



To confirm the source AR of the CME, first we look at STEREO-A & B movies to make sure that the CME is Earth-directed. We then look at AIA movies, and SolarMonitor.org to find flare activity & timing, and NOAA AR number & position of the AR on the solar disk.



AR Magnetic Non-potentiality Parameters:

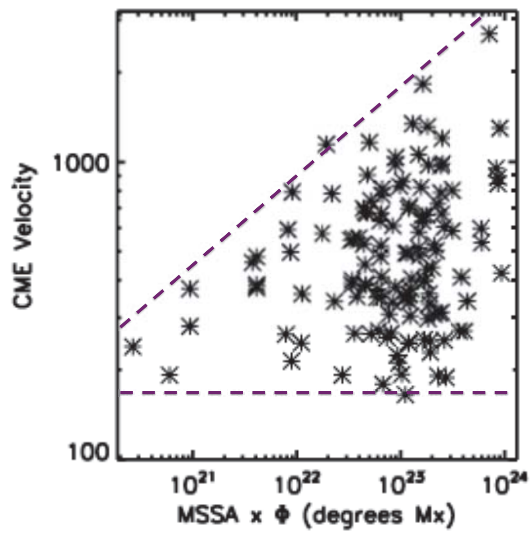
Signed Shear Angle (SSA): $SSA = \tan^{-1}\left(\frac{B_{yo}B_{xp} - B_{yp}B_{xo}}{B_{xo}B_{xp} + B_{yo}B_{yp}}\right)$: Tiwari et al 2009, ApJL;

Force-free parameter (α_g): $\alpha_g = \frac{\sum\left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y}\right)B_z}{\sum B_z^2}$: Tiwari et al 2009, ApJ;

Gradient weighted neutral line length (WL_{SG}): $WL_{SG} = \int |\nabla Bz| dl$: Falconer et al 2008, ApJ;

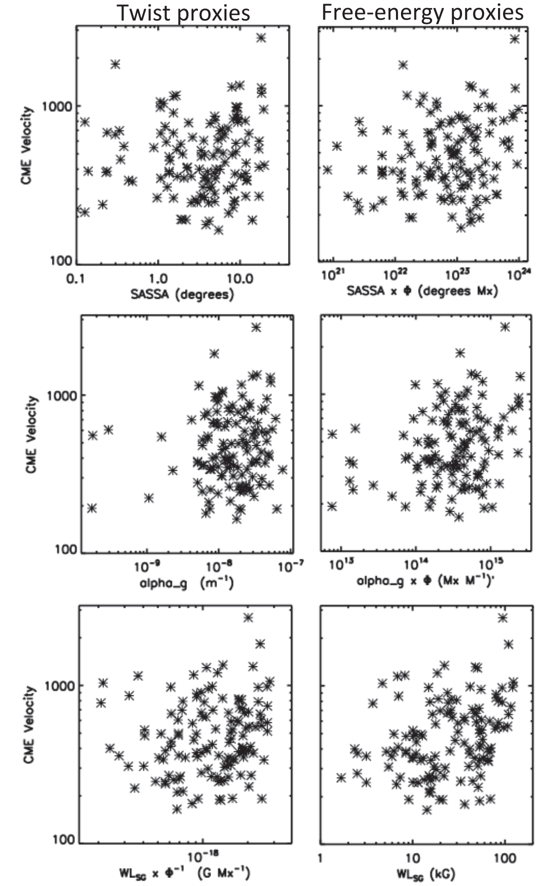
Results

CME Speed vs Various Magnetic Non-potentiality Parameters of the Source AR



(a free-energy proxy)

Twist proxies Free-energy proxies



SASSA: Spatially Averaged SSA

MSSA : Median of SSA: both SASSA and MSSA measure twist at a given height irrespective of shape and force-free nature of spot

α_g : measures gradient of twist per unit axial length; a proxy for global twist

ϕ : total unsigned magnetic flux, this is proportional to area of the AR

WL_{SG} is a free energy proxy

Discussion and Conclusions

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A right-angled triangle shape of the scatter plots of CMEs speed vs free energy parameters is most noticeable for MSSA × ϕ, giving the sharpest CME speed limit increasing with AR free energy. Each of the other three free-energy proxies shown here shows the CME speed limit better than its corresponding twist proxy. Evidently the fastest CMEs are produced by ARs having the most free energy. Such ARs also produce many slower CMEs. Least non-potential ARs do not produce fast CMEs. We are collecting more data to reduce scatter and improve statistics. One caution is that the LASCO CME velocities used here are linear fit plane-of-the-sky values, and therefore underestimated.

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